# Lateral shearing interferometry for high-NA EUV wavefront metrology

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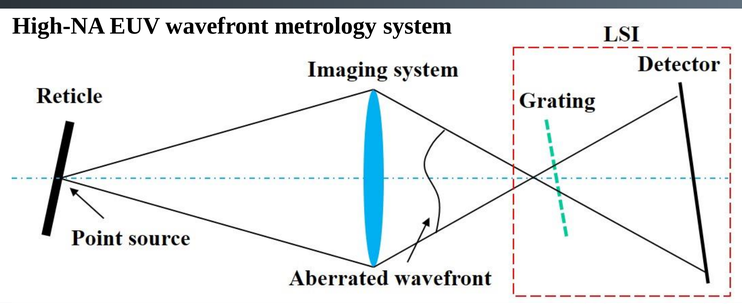
## Introduction

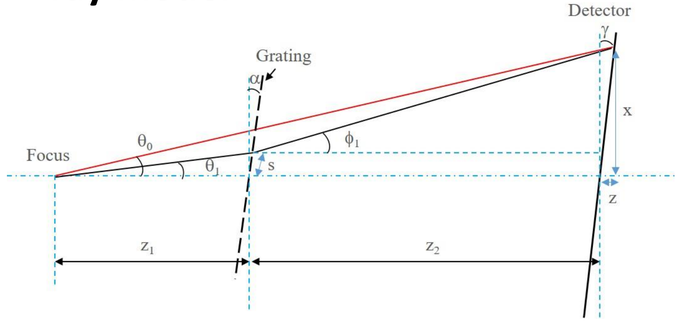
Next-generation EUV exposure tools will have numerical apertures (NA) exceeding 0.5, providing an ultimate resolution below 8 nm. In order to reach this resolution, the optical aberrations must be characterized and removed.




A pinhole array at the reticle is used to produce an ideal spherical wavefront. After passing through the optic, the wavefront may be aberrated due to the misalignment of the imaging system. A lateral shearing interferometer is used to measure these aberrations to guide the alignment of the system

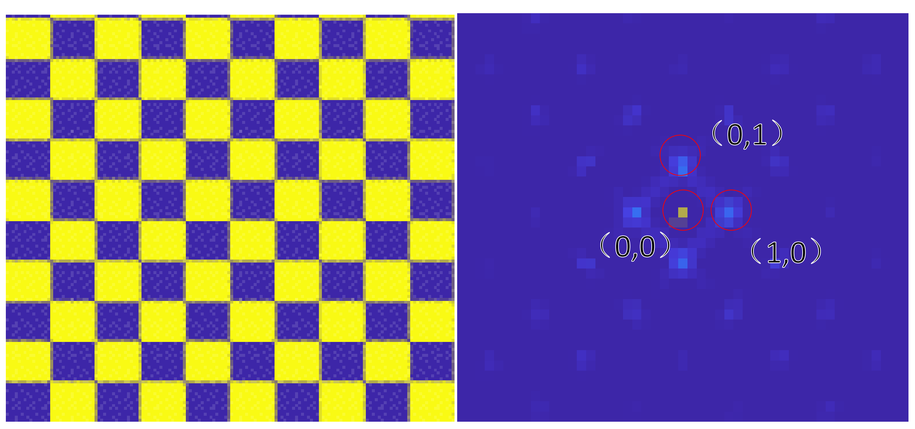
## Theory

### 2-ray model




At high NA, LSI is susceptible to systematic aberrations. A geometric model called 2-ray model is used to understand the systematic effects contained in the shearing interferograms. By calculating the optical path difference (OPD) of the two rays, the wavefront derivatives can be obtained. The 2-ray model agrees with rigorous diffraction models and has better computation times.

### Derivative wavefront extraction




We use a checkerboard grating to generate the shear and record the derivative wavefronts. Phase stepping is achieved by translating the grating enabling temporal domain analysis.

### Wavefront reconstruction

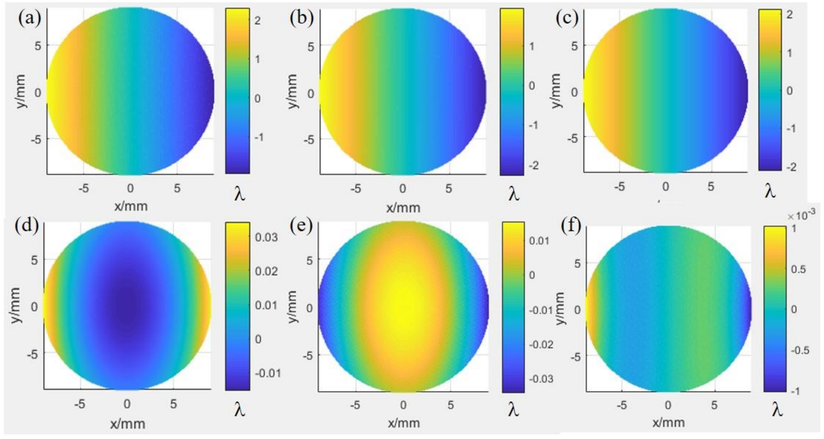
$Z_k(x,y) \rightarrow$ **2-ray model** $\rightarrow Z_{kx}(x,y), Z_{ky}(x,y)$

$W(x,y)=\Sigma c_k * Z_k(x,y) \rightarrow$ **2-ray model** $\rightarrow \Delta W_x(x,y), \Delta W_y(x,y)$

The wavefront is reconstructed based on a least-squares algorithm.
(1) Zernike polynomials are used to express the wavefront.
(2) The sheared basis is produced by 2-ray model.
(3) The coefficients can be calculated by fitting the extracted wavefront derivatives to the basis.

## Simulation

### Null interferogram

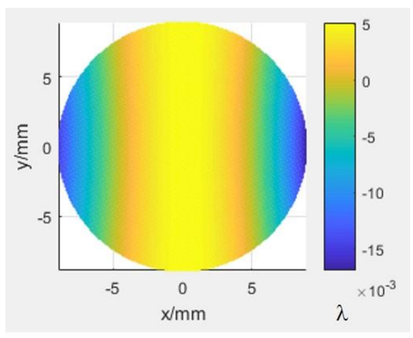



OPD contained in null interferogram: (a) (0, 0) and (+1, 0) orders; (b) (0, 0) and (-1, 0) orders; (c) average value of (a) and (b); (d-f) tilt removed results of (a-c)

### Grating and detector tilt

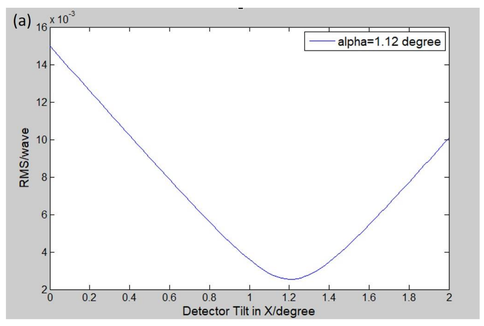
Reason for grating tilt (1.12 degree):

- Reticle is tilted for reflective illumination
- Periodic point source array is used to enhance the flux



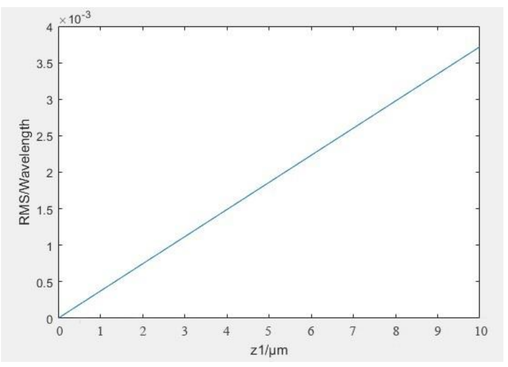

OPD with the grating tilt 1.12 degree

Reason for detector tilt: minimize systematic error




The minimum RMS value is obtained at the detector tilting about 1.2 degree, which corresponds to the chef ray angle.

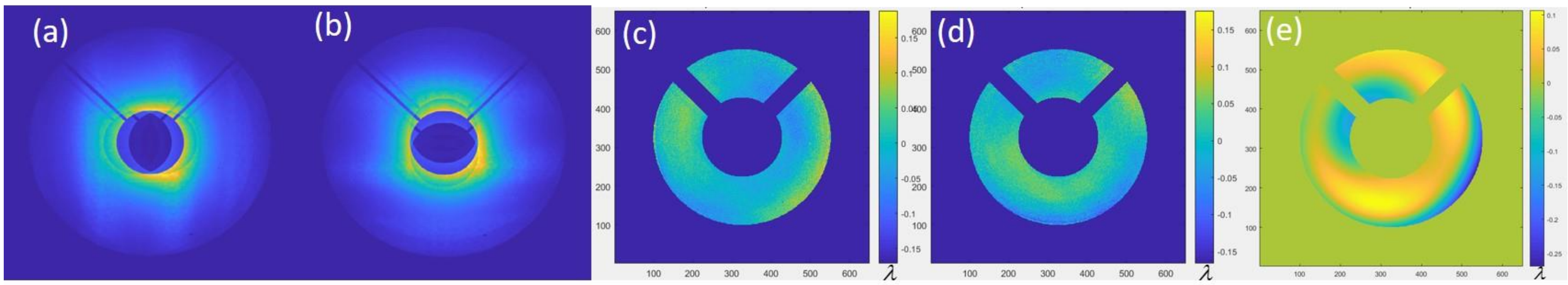
### Grating position




Impact of grating position error is linear allowing it to be removed by repeating measurement through focus.

## Experiment

**The experiment was implemented at the Berkeley MET5. Wavelength: 13.5 nm NA: 0.5 Grating pitch: 234 nm Grating and detector tilt: 1.12° Grating distance: 0.6 um**




Experiment results: (a-b) respective shearing interferograms in x and y directions; (c-d) wavefront derivatives extracted from (a-b); (e) reconstructed wavefront

RMS value: 0.063λ

## Conclusion

- New high speed 2-ray method developed to understand systematic aberrations in LSI and precompute reconstruction basis
- New analysis indicates that CCD should be at 1.2 degrees instead of parallel to image/grating plane
- Impact of grating position error is linear allowing it to be removed by repeating measurement through focus

### Future Work

- Simulate multiplexing LSI configuration
- Explicitly study impact of mechanical stability/drift
- Develop method to handle non-uniform phase stepping

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